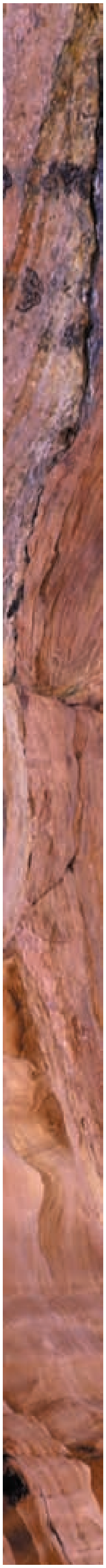
Activity 2 Detecting Earthquake Waves



Goals

In this activity you will:

- Construct a simple seismometer.
- Record motion in two dimensions and also within a fixed time frame.
- Understand how seismometers record earthquake waves.
- Recognize P waves, S waves, and surface waves on seismograms.
- Read a graph to determine the distance to the earthquake focus.
- Locate the epicenter from time–distance graphs.

Think about It

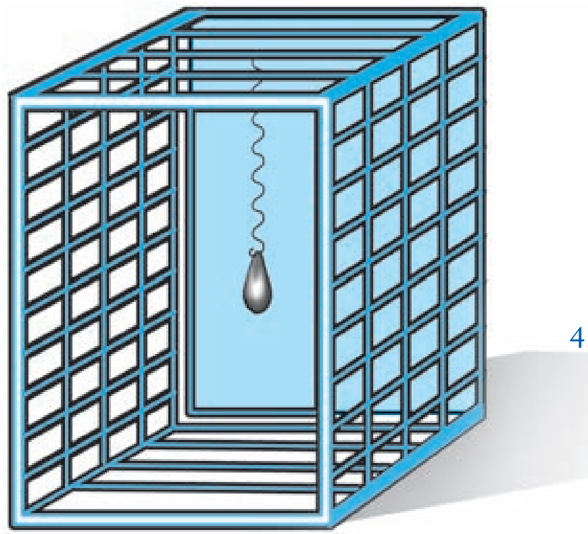
Some of the energy released by an earthquake takes the form of seismic waves. Surface waves are responsible for most earthquake destruction.

- What specific observations would you want to make to study an earthquake?
- How could you detect and record the arrival of earthquake waves: P waves, S waves, and surface waves?

What do you think? Record your ideas about these questions in your *EarthComm* notebook. Be prepared to discuss your responses with your small group and the class.

Investigate

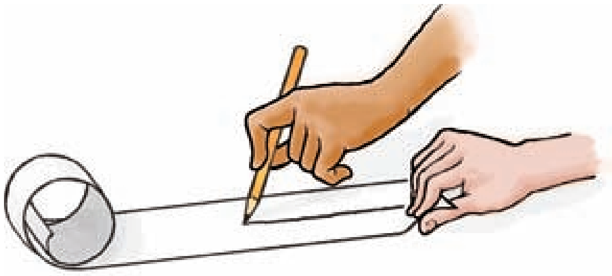
1. Attach one end of a spiral spring or thick rubber band to a small, heavy weight (a non-lead fishing-line sinker would work well). Attach the other end of the spring or rubber band to the bottom of a rectangular, open-sided storage box, such as a small milk crate. Turn the box upside down so that the weight is suspended and hanging freely.



2. Move the frame of the box rapidly back and forth (horizontally). Now move the box vertically up and down. Move it back in forth in one direction, then back and forth in the other direction.
   a) In your notebook, write a careful description of what you observe.
   b) Are the motions you generate similar to the motions produced by the Slinky in **Activity 1**, or different?
   c) How would you describe the motions of the weight in comparison to the motions you impart to the box?

Be sure the spring and weight are securely fastened to the crate.

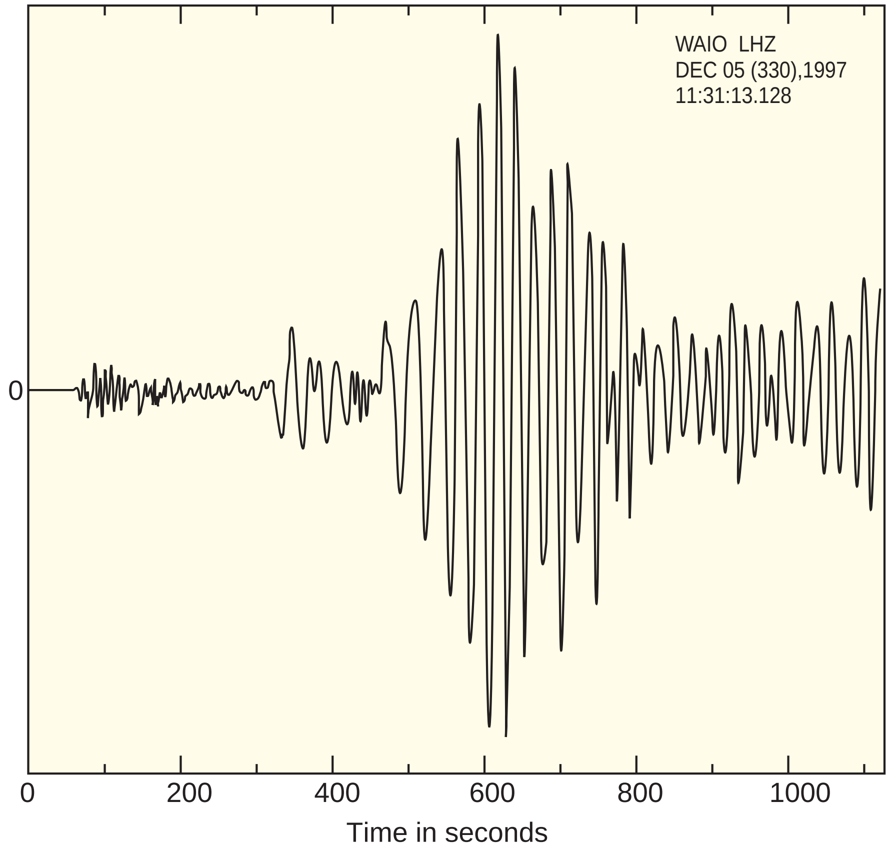
3. Obtain a piece of heavy paper or light cardboard and a very soft pencil or thin felt-tipped marker. Hold the marker firmly in place above the paper so that its tip is just touching the paper. This can be done by having the member of your group with the steadiest hand hold the marker in place above the paper. Have another group member move the paper under the marker in order to write the word "Earthquake" in cursive. Move only the paper, not the pen.
   a) Record what you observe and how this writing is achieved.
4. Drag the paper across the table smoothly toward you (with the tip of the marker touching the paper). Then pull the paper toward you again, but this time jiggle it back and forth perpendicular to the direction in which you're pulling.
   a) What does the line look like when the paper was pulled smoothly toward you?
   b) What does the resulting line look like when the paper was jiggled?



5. Repeat step 4, but this time use a timer or the second hand on a watch to record the time it takes to pull the paper through. Use a roll of adding machine paper this time so you have a strip of paper a meter or so long. Have a third person make a little mark on the edge of the paper strip every second as you move the strip along.

6. Examine a record of a real earthquake as shown in the figure below.
   a) Is the size (height) of the recorded wave the same for the entire duration shown on the seismogram?
   b) Is the shape of the recorded wave the same for the entire duration shown on the seismogram?

7. Make or obtain a copy of the diagram showing a real earthquake.
   a) Label the arrival of the P wave and the S wave.
   b) How much time separates the arrival of the two waves?
   c) Use the diagram and the difference in arrival times to determine the distance from the focus to the seismometer.



Reflecting on the Activity and the Challenge

You constructed a simple instrument that recorded passing vibrations. Your instrument used a stationary mass (like the fishing-line sinker) to provide a fixed reference against which vertical and horizontal movement could be compared. By marking time on your record, you could determine the "arrival" of the waves you generated. What you created is a very simple seismometer. A seismometer is a device for measuring shaking. You also made a seismogram, or record of shaking. Geologists use similar (but more complex) instruments to record passing earthquake waves. Time is also marked on their records. This allows the arrival times of P waves, S waves, and surface waves to be determined.

Geo Words

seismometer: an instrument that measures seismic waves. It receives seismic impulses and converts them into a signal like an electrical voltage.

Digging Deeper

RECORDING EARTHQUAKE WAVES

Seismometers

A **seismometer** works on the principle of inertia, the tendency for a mass at rest to remain at rest. Seismometers similar to the device you built were first used in the 1800s. They had a cylinder coated with soot and a stylus that scratched a mark as it registered vibrations. In today's instruments (*Figure 1*), the relative motion between the mass and its frame creates an electric signal. The signal is then amplified and transmitted to a recording destination. The destination may be a) ink pens writing on paper, b) a narrow beam of light that leaves a record of the vibrations on photographic paper, c) a device that records a magnetic signal on tape, or d) a computer screen. It takes three seismometers to record all the motions of the ground during an earthquake. Two horizontal cylinders at right angles to each other record sideways motions (north–south, east–west). The third cylinder is vertical. It records up and down motions.

Figure 1 In the 1960s, a worldwide network of seismometers was developed to verify nuclear test-ban treaties. When a nuclear device is tested, seismometers around the world record the seismic waves that result from the blast.

Instruments used to detect earthquakes also record any motion of the ground to which they are attached. These motions can be natural (earthquakes, landslides) or caused by humans (large trucks, passing airplanes and helicopters, blasting during construction, nuclear bombs).

Interpreting Seismograms

A **seismogram** is a written or mechanically produced record of earthquake waves. *Figure 2* shows a seismogram recorded at Dallas, Texas. Note the separation of P waves and S waves on the seismogram. This seismogram was recorded about 1600 km from the earthquake's focus. If it had been recorded near the focus, the two waves would appear much closer together. All the waves are produced during the rupture. As distance from the focus increases, the separation and arrival times between the wave types increase because they travel at different speeds.

Geo Words

seismogram: the record made by a seismometer.

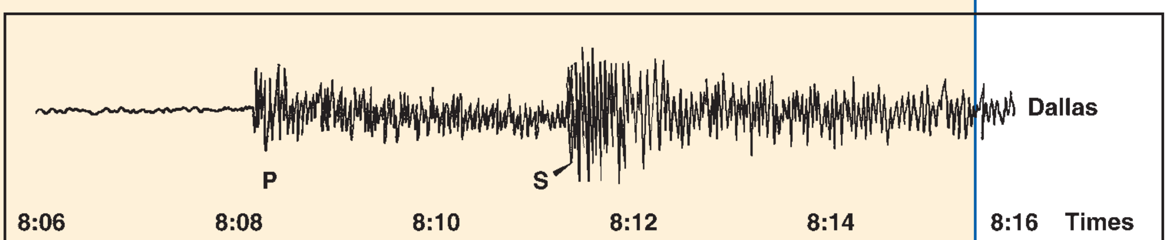


Figure 2 Seismogram recorded in Dallas, Texas.

P waves travel the fastest through the Earth, so they arrive first at a distant station. S waves arrive shortly after. Waves that arrive after the direct P waves complicate the seismogram. Various reflected and refracted P and S waves bounce off (are reflected at) layers of Earth's interior and eventually reach the station.

Using Travel-Time Curves

P and S waves travel at different speeds , so they arrive at different times at a seismological station. The difference in their arrival times increases with the distance from the focus. Travel-time curves (see *Figure 3* on the next page) show this relationship.

Check Your Understanding

1. What is the function of a seismometer?
2. a) How many seismometers do you need at a given place to fully record the motions arising from earthquake waves?

   b) How should these seismometers be oriented, and why?
3. What is a seismogram?
4. What information is provided by a travel-time curve?

The graph shows the data from a magnitude 8 earthquake in the Kuril Islands on 3 December 1995. Here you can see the relationship between distance and the difference in arrival times for P waves and S waves.

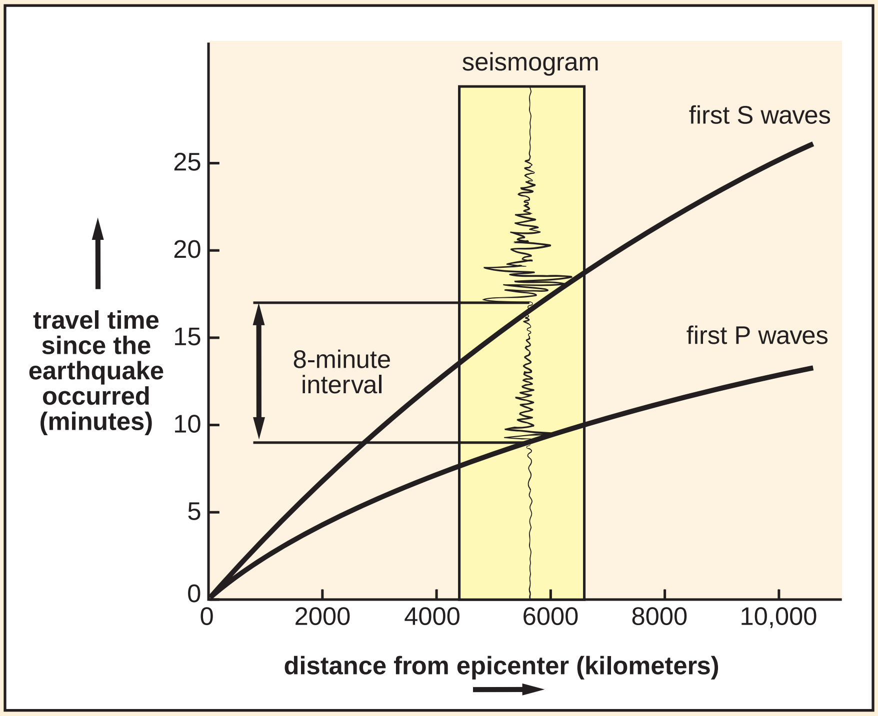


Figure 3 Travel-time curve for an earthquake.

Understanding and Applying What You Have Learned

1. a) Where would be the best place to put a seismometer in your school? Why would you choose this location?

   b) Where would be the worst place(s) in your school to put a seismometer? Why should this (these) location(s) be avoided?

   c) Where in your community might be a good place to put a seismometer? Why?

   d) At what locations in your community is it unwise to place a seismometer? Why?
2. a) How are the devices you worked with in this activity good models of a modern seismometer?

   b) In what respects are they poor models?

   c) What could you do to improve your models?

3. What advantages would be gained by having more seismometers at a particular location?
4. Not all vibrations of the Earth are made by natural earthquakes.
   a) Write in your notebook as many things as you can think of that could cause strong vibrations of the Earth's surface.
   b) How might you be able to distinguish seismograms of "natural" earthquakes from "human-made" earthquakes?

Preparing for the Chapter Challenge

Write a summary of this activity for your brochure. Include a concise, simple, but accurate description of how to detect earthquake waves and locate epicenters. Also record where to place a seismometer at your school (or somewhere else in your community). Explain why you chose this location.

Inquiring Further

1. **History of science**

   The study of earthquakes has a fascinating history. Humans have always felt the effects of earthquakes. Early civilizations interpreted the shaking of the Earth in different ways. How have the methods used to study earthquakes changed over time? Use electronic or print resources to prepare a report.

In 132 A.D., a Chinese scholar named Chang Heng made one of the earliest known devices used to record the occurrence of an earthquake.

2. **Recent seismic activity**

   Visit the *EarthComm* web site for a description of how to conduct an on-line investigation into seismic waves that travel complicated paths within the Earth.

3. **Virtual earthquakes**

   Find out about the Virtual Earthquake web site at the *EarthComm* web site. Practice using seismographs to find an earthquake epicenter. Simulate an earthquake in the region of your choice. Print out a record of your results. Include the seismograms and the map showing the epicenter location, but do not do the magnitude activity at this time.